

What is claimed is:

1. A method for characterizing a geometric element of an object comprising the steps of:

5 positioning a target adjacent a calibration geometric element, the target comprising at least two differentially detectable features having a known geometric relationship to each other;

calibrating the target by determining a relationship of the target features to the calibration geometric element of the object;

10 moving the calibrated target adjacent a geometric feature of an object desired to be characterized; and

applying photogrammetry to the target features and the desired geometric feature to spatially characterize the desired geometric feature.

15 2. The method recited in Claim 1, wherein the relationship-determining step comprises:

positioning the target at least partially upon the calibration geometric element;

applying detectable features to the calibration geometric element; and

20 applying photogrammetry to the target features and the calibration geometric element features to determine a relationship between the target and the calibration geometric element.

3. The method recited in Claim 1, wherein the photogrammetry-applying step comprises the steps of:

taking at least two photographs of a portion of the object, each photograph containing the target features and at least a portion of the desired geometric feature, each photograph taken from a different perspective relative to the object;

calculating relative positions of the target features and the desired geometric feature; and

performing a geometric calculation on the relative positions to determine spatial coordinates of the geometric element.

4. The method recited in Claim 3, wherein the photograph-taking step comprises taking digital photographs, and wherein the calculating and performing steps are performed in a computer having photogrammetric analysis software resident therein.

5. The method recited in Claim 1, wherein the target features comprise imagable shapes.

6. The method recited in Claim 5, wherein the target features comprise a unitary first feature having a first shape and a plurality of second features having a second shape different from the first shape.

7. The method recited in Claim 6, wherein the first feature is positioned substantially centrally on the calibrated target.

8. The method recited in Claim 7, wherein a first one of the second features is positioned at a first distance from the first feature and a second one of the second features is positioned at a second distance from the feature unequal to the first distance.

9. The method recited in Claim 1, wherein the calibration geometric element has a substantially planar face and the target features are substantially coplanar.

10. The method recited in Claim 9, wherein the desired feature comprises a plane, and the target moving step comprises moving at least a portion of the target onto the plane.

11. The method recited in Claim 9, wherein the desired feature comprises a plane and the target moving step comprises moving the target to a position perpendicular to the plane.

12. The method recited in Claim 9, wherein:
the desired feature comprises an edge formed by a first plane and a second plane;

the target moving step comprises moving at least a portion of the target into a known relationship with the first plane; and

the photogrammetry-applying step comprises spatially characterizing the first plane; and further comprising the steps, following the photogrammetry-applying step, of:

5 moving the target adjacent the second plane;

applying photogrammetry to the target features and the second plane to spatially characterize the second plane; and

analyzing the characterizations of the first and the second plane to determine a spatial characterization of the edge.

10 **13.** The method recited in Claim 9, wherein:

the desired feature comprises a corner formed by a first plane, a second plane, and a third plane;

15 the target moving step comprises moving at least a portion of the target into a known relationship with the first plane; and

the photogrammetry-applying step comprises spatially characterizing the first plane; and further comprising the steps, following the photogrammetry-applying step, of:

moving the target adjacent the second plane;

20 applying photogrammetry to the target features and the second plane to spatially characterize the second plane;

analyzing the characterizations of the first and the second plane to determine a spatial characterization of a first edge formed by the first and the second plane;

moving the target adjacent the third plane;

applying photogrammetry to the target features and the third plane to spatially
characterize the third plane;

analyzing the characterizations of the first and the third plane to determine
5 a spatial characterization of a second edge formed by the first and the third plane; and

analyzing the characterizations of the first and the second edges to spatially
characterize the corner formed by the first, the second, and the third planes.

14. The method recited in Claim 9, wherein:

10 the desired feature comprises a center point of a circular object;

the target has a first planar face containing the target features and a second
planar face joined to the first planar face at a known angle;

the target moving step comprises moving at least a portion of the target so
that both the first face and the second face are in contact with the circular object at a first
15 and a second tangent point, respectively; and

the photogrammetry-applying step comprises spatially characterizing the first
face and the first tangent point; and further comprising the step, following the
photogrammetry-applying step, of:

analyzing the characterizations of the first plane and the first tangent point
20 to determine a spatial characterization of the center point of the circular object.

15. The method recited in Claim 9, wherein:

the desired feature comprises a center line of a substantially cylindrical object;

the target moving step comprises moving at least a portion of the target to a first location against the cylindrical object;

5 the photogrammetry-applying step comprises spatially characterizing a first center point of the cylindrical object; and further comprising the steps, following the photogrammetry-applying step, of:

again moving the target to a second location against the cylindrical object in spaced relation from the first location;

10 applying photogrammetry to the target features to spatially characterize a second center point of the cylindrical object; and

analyzing the characterizations of the first and the second center points to determine a spatial characterization of the cylindrical object center line.

15 **16.** A method for characterizing a geometric element of an object comprising the steps of:

positioning a calibrated target adjacent a geometric feature of an object desired to be characterized, the calibrated target comprising at least two differentially detectable features having a known geometric relationship to each other, the features
20 further having a known geometric relationship to a surface of the object; and

applying photogrammetry to the calibrated target features and the desired geometric feature to spatially characterize the desired geometric feature.

17. The method recited in Claim 16, wherein the photogrammetry-applying step comprises the steps of:

taking at least two photographs of a portion of the object, each photograph containing the calibrated target features and at least a portion of the desired geometric feature, each photograph taken from a different perspective relative to the object;

calculating relative positions of the calibrated target features and the desired geometric feature; and

performing a geometric calculation on the relative positions to determine spatial coordinates of the geometric element.

18. The method recited in Claim 17, wherein the photograph-taking step comprises taking digital photographs, and wherein the calculating and performing steps are performed in a computer having photogrammetric analysis software resident therein.

19. The method recited in Claim 16, wherein the calibrated target features comprise imagable shapes.

20. The method recited in Claim 19, wherein the calibrated target features comprise a unitary first feature having a first shape and a plurality of second features having a second shape different from the first shape.

21. The method recited in Claim 20, wherein the first feature is positioned substantially centrally on the calibrated target.

22. The method recited in Claim 21, wherein a first one of the second features is positioned at a first distance from the first feature and a second one of the second features is positioned at a second distance from the feature unequal to the first distance.

23. The method recited in Claim 16, wherein the calibrated target features are substantially coplanar.

24. The method recited in Claim 16, wherein the desired feature comprises a plane, and the calibrated target moving step comprises moving at least a portion of the calibrated target onto the plane.

25. The method recited in Claim 16, wherein the desired feature comprises a plane and the calibrated target moving step comprises moving the calibrated target to a position perpendicular to the plane.

26. The method recited in Claim 16, wherein:
the desired feature comprises an edge formed by a first plane and a second plane;

the calibrated target moving step comprises moving at least a portion of the calibrated target into a known relationship with the first plane; and

the photogrammetry-applying step comprises spatially characterizing the first plane; and further comprising the steps, following the photogrammetry-applying step, of:

again moving the calibrated target adjacent the second plane;

applying photogrammetry to the calibrated target features and the second plane to spatially characterize the second plane; and

analyzing the characterizations of the first and the second plane to determine a spatial characterization of the edge.

27. The method recited in Claim 16, wherein:

the desired feature comprises a corner formed by a first plane, a second plane, and a third plane;

the calibrated target moving step comprises moving at least a portion of the calibrated target into a known relationship with the first plane; and

the photogrammetry-applying step comprises spatially characterizing the first plane; and further comprising the steps, following the photogrammetry-applying step, of:

again moving the calibrated target adjacent the second plane;

applying photogrammetry to the calibrated target features and the second plane to spatially characterize the second plane;

analyzing the characterizations of the first and the second plane to determine a spatial characterization of a first edge formed by the first and the second plane;

again moving the calibrated target adjacent the third plane;

applying photogrammetry to the calibrated target features and the third plane
to spatially characterize the third plane;

analyzing the characterizations of the first and the third plane to determine
5 a spatial characterization of a second edge formed by the first and the third plane; and

analyzing the characterizations of the first and the second edges to spatially
characterize the corner formed by the first, the second, and the third planes.

28. The method recited in Claim 16, wherein:

10 the desired feature comprises a center point of a circular object;

the calibrated target has a first planar face containing the target features and
a second planar face joined to the first planar face at a known angle;

the calibrated target moving step comprises moving at least a portion of the
calibrated target so that both the first face and the second face are in contact with the
15 circular object at a first and a second tangent point, respectively; and

the photogrammetry-applying step comprises spatially characterizing the first
face and the first tangent point; and further comprising the step, following the
photogrammetry-applying step, of:

analyzing the characterizations of the first plane and the first tangent point
20 to determine a spatial characterization of the center point of the circular object.

29. The method recited in Claim 16, wherein:

the desired feature comprises a center line of a substantially cylindrical object;

the calibrated target moving step comprises moving at least a portion of the calibrated target to a first location against the cylindrical object;

5 the photogrammetry-applying step comprises spatially characterizing a first center point of the cylindrical object; and further comprising the steps, following the photogrammetry-applying step, of:

again moving the calibrated target to a second location against the cylindrical object in spaced relation from the first location;

10 applying photogrammetry to the calibrated target features to spatially characterize a second center point of the cylindrical object; and

analyzing the characterizations of the first and the second center points to determine a spatial characterization of the cylindrical object center line.

15 **30.** A system for characterizing a geometric element of an object comprising:
a movable calibrated target comprising at least two differentially detectable features having a known geometric relationship to each other; and

a photogrammetric analysis system for:

determining a relationship of the calibrated target to a calibration

20 geometric element; and

spatially characterizing a geometric feature of an object desired to be characterized using the calibrated target features.

31. The system recited in Claim 30, further comprising detectable features applicable to the calibration geometric element for facilitating the determination of the relationship of the calibrated target to the calibration geometric element.

5 **32.** The system recited in Claim 30, wherein the photogrammetric analysis system comprises at least one camera for taking at least two photographs of a portion of the object, each photograph containing the calibrated target features and at least a portion of the desired geometric feature, each photograph taken from a different perspective relative to the object.

10 **33.** The system recited in Claim 32, wherein the photogrammetric analysis system comprises means for calculating relative positions of the calibrated target features and the desired geometric feature and for performing a geometric calculation on the relative positions to determine spatial coordinates of the geometric element.

15 **34.** The system recited in Claim 33, wherein the camera comprises a digital camera, and wherein the photogrammetric analysis system further comprises a computer and photogrammetric analysis software resident in the computer.

20 **35.** The system recited in Claim 30, wherein the calibrated target features comprise imagable shapes.

36. The system recited in Claim 35, wherein the calibrated target features comprise a unitary first feature having a first shape and a plurality of second features having a second shape different from the first shape.

5 **37.** The system recited in Claim 36, wherein the first feature is positioned substantially centrally on the calibrated target.

10 **38.** The system recited in Claim 37, wherein a first one of the second features is positioned at a first distance from the first feature and a second one of the second features is positioned at a second distance from the feature unequal to the first distance.

15 **39.** The system recited in Claim 30, wherein the calibration geometric element has a substantially planar face and the calibrated target features are substantially coplanar.

20 **40.** The system recited in Claim 30, wherein the calibrated target further comprises means for affixing the calibrated target to a portion of the object.

41. The system recited in Claim 40, wherein the affixing means comprises a magnet for affixing to a metallic object.

42. The system recited in Claim 40, wherein the affixing means comprises an adhesive.

43. The system recited in Claim 30, wherein the calibrated target comprises a substantially planar target element and a planar base affixed to the target element at a predetermined angle.

5

44. The system recited in Claim 30, wherein the calibrated target has a first planar face containing the target features and a second planar face joined to the first planar face at a known angle.